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Depletion of High Plains Wheatlands

By H. H. **Finnell**, *research specialist, Soil Conservation Service, Goodwell, Okla.*[1]

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VALUABLE AIR-BORNE DUST

THE light high-flying particles of soil show signs of being more important to the fertility of wheatlands in the great new dry-land winter-wheat belt of the southern High Plains than was formerly realized. This wheat-growing area is called "new" because much of the land has been cultivated less than 30 years; most of it not longer than 50 years.

It was the finely divided, half-rotted organic matter that made the early dust storms of the 1930's so black and awful looking. It was the loss of this dust that made the first serious inroads on the soil-fertility reserves of the High Plains.

The dust removals from 200 wind-swept counties, if heaped together, would have made an imposing pile of soil. Of equal or greater significance was the richness of this dust in fertility. Nearly one-fourth of the material in the first soil drift that piled up in a fence row on the Panhandle Experiment Station at Goodwell, Okla., in the early windstorm days of 1933 was organic matter. But the organic materials came from topsoils that averaged less than 2 percent organic matter. They had been separated by wind action from the exposed surface layers of the topsoil.

The incident illustrates the fact that finely divided organic matter in the soil is unusually free to move when exposed, and that soil particles are assorted as readily while being carried away by flowing air as when carried by flowing water.

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[1] The author is indebted to the several field observers who cooperated in collecting and standardizing the data used in this study. In Colorado, they were Bruno Klinger, V. A. Killerlain, and D. K. Daubert; in Kansas, Ellis M. Baker and Oliver R. Nuzum; in New Mexico, J. E. Chapman, Rannell R. Jones, and Wm. R. White; in Texas, Olmon W. Sweat; and in Oklahoma and Texas, Roy V. Bailey.

The organic materials are valuable in several respects. The total organic content of the soil has been shown to be closely associated with the total nitrogen content, and nitrogen is believed to be the chief plant-food element limiting production from High Plains soils. Organic matter, raw and decomposed, also plays a leading part in wind-erosion control and in the productive water relations of soils.

Did the removal of soil by wind action harm the land? Some farmers noted that the wind, in blowing the soil off the fields down to plow depth, removed troublesome weed seeds as well as topsoil. This left the land clean and easily cultivated for more than one growing season.

However, productivity seemed to be lower after the dust days were over. During a resurvey of erosion that was in progress while the excellent wheat crop of 1947 was on the ground, marked differences were noted in the greenness of the plants in the various fields. These differences indicated sharp contrasts in the amount of nitrogen available to the plants. The pale and sickly looking wheat as a rule proved to be on land that had been badly eroded. Wheat farmers generally over the area noted this close relation between low plant vigor and soil erosion.

A study of land use experience from 1936 to 1947[2] gave a clue to fertility trends, which were investigated. This is a report of some of the things learned about these trends, and about the effects of soil blowing on the yield and dependability of crops.

EROSION MEASUREMENTS

It is difficult to obtain an accurate quantitative measure of wind erosion. Measuring it is not as easy as measuring water erosion by catching rainwash in pits, as in areas of high rainfall.

Coldwell and others[3] in 1937 set up elevation transects totalling a few thousand yards in length on the soil conservation demonstration project at Dalhart, Tex., to measure wind erosion. Bench marks were established and engineering surveys were made yearly to determine the extent of removals and accumulations taking place on soils of different texture under various conditions of plant cover. Useful data on rate of erosion removals were obtained in this way.

For the High Plains in general, however, not enough exact measurements have been made of erosion by wind to permit expressing erosion in inches of soil removed or tons lost per acre. Nor is it possible to capture all the particles of soil taken off by wind, weigh them, and analyze them. It is more practical to estimate the degree of erosion and classify it in broad but useful terms—a procedure that has been widely accepted throughout the country. For the area covered by this report, a "slight" degree of wind erosion represents the removal of not more than 1 inch of topsoil, "moderate" the removal of 1 to 3 inches, and "severe" the removal of 3 to 4 inches. The approximate removals as denoted by degrees of erosion are known to correspond to a consistent lowering of yields which can be expressed in bushels per acre of lost productive capacity.

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[2] FINNELL, H. H. LAND USE EXPERIENCE IN SOUTHERN GREAT PLAINS. U. S. Dept. Agr. Cir. 820. 1949.

[3] COLDWELL, A. E., LOEWEN, P. R., AND WHITFIELD, C. J. RELATION OF VARIOUS TYPES OF VEGATATIVE COVER TO SOIL DRIFT. Amer. Soc. Agron. Jour. 34: 702-710. 1942.

PLAN OF STUDY

This study is based on an analysis of 799 cases for which yield and erosion information was available for the 5-year period 1945-49. This was a period of wheat production without a general crop failure during which an average of 18 bushels per acre was harvested from land cropped each year to wheat and 29¼ bushels per acre every second year from wheat after fallow.

The sample areas included parts of Baca and Prowers Counties, Colo.; Sherman and Scott Counties, Kans.; Texas and Beaver Counties, Okla.; Ochiltree and Deaf Smith Counties, Tex. Supplementary data were obtained from Roosevelt, Curry, Quay, Harding, and Union Counties, N. Mex.

The location map (fig. 1) shows the part of the Great Plains wheat country represented by this study, and the counties in which the specific areas sampled in the study were situated.

The available records of winter-wheat crops were brought together from soil conservation districts of the area in which erosion had been mapped during the period 1936-42. The records were obtained through the help of Soil Conservation Service regional offices located at Fort Worth, Tex.; Lincoln, Nebr.; and Albuquerque, N. Mex.; and the State experiment stations in Colorado, Kansas, Oklahoma, New Mexico, and Texas. Farmers who were both interested and painstaking helped by keeping accurate field records.

The crop-yield data were gathered only for fields that were uniform as to soil, slope, and erosion conditions. The specific physical land conditions sampled were typical of the prevailing agriculture in the respective communities.

The rain-gage network of the U. S. Weather Bureau, supplemented by four experimental gages furnished by the Soil Conservation Service for each Weather Bureau location, were used as a basis for seasonal rainfall information. The majority of the special rain gages were located on the farms of persons cooperating in the study. Many records were also taken on

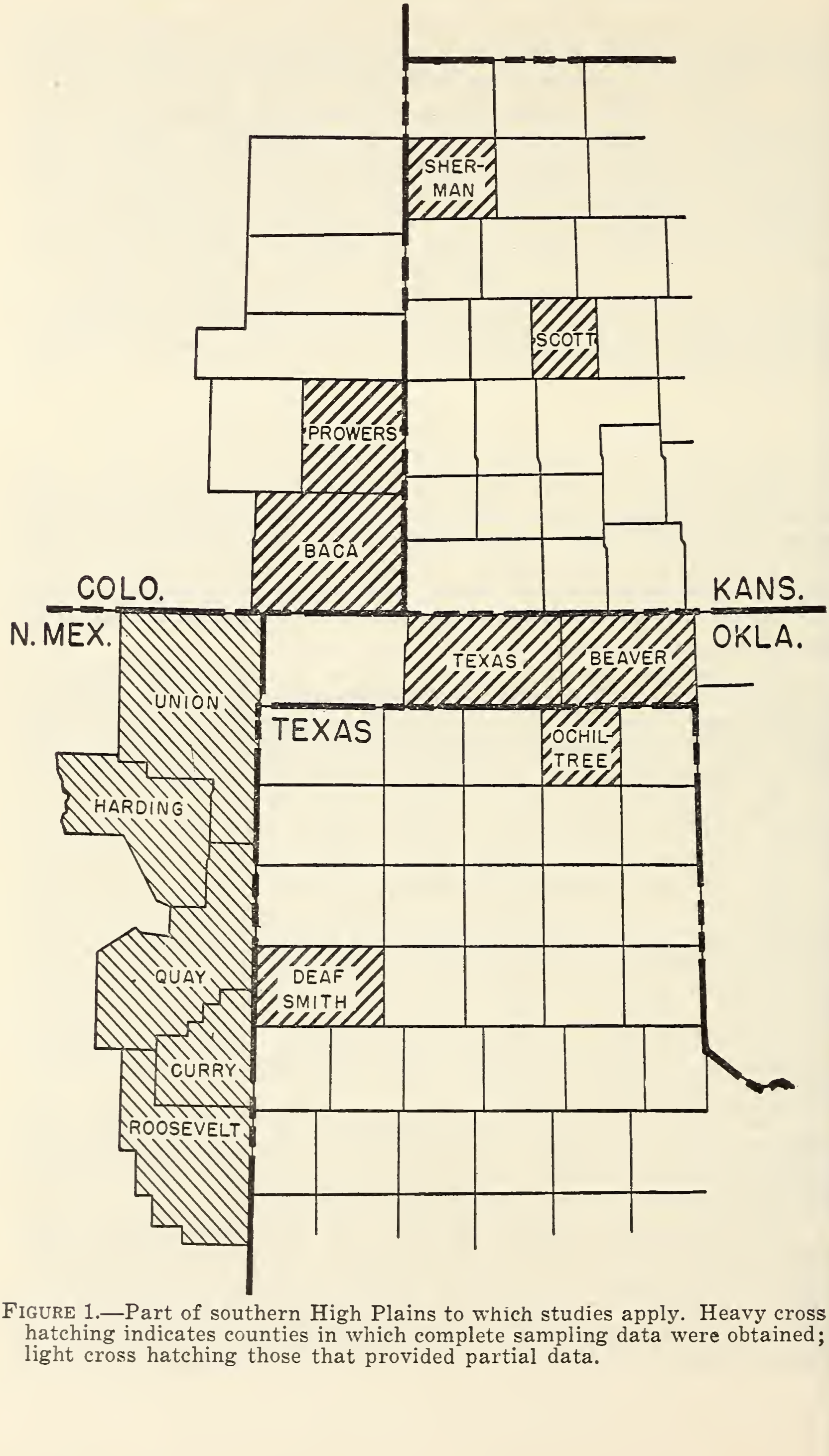

FIGURE 1.—Part of southern High Plains to which studies apply. Heavy cross hatching indicates counties in which complete sampling data were obtained; light cross hatching those that provided partial data.

adjoining or nearby farms, none of which were more than 4 miles from the nearest rainfall station.

With some exceptions, the same sample areas were used throughout the 5-year study period. Substitutions of fields were made on the basis of unsatisfactory cooperation, changes in land ownership, or other unforeseen circumstances, but each crop-year record was treated as a unit of information. Each record, before it was used, was examined to make sure that the information needed for the study was complete, beginning in each case with the harvest of the previous crop and extending through yield determination of the crop in question.

All yields are reported on the basis of sowed acreage and calculated to the nearest even bushel per acre.

Soil-moisture penetrations were recorded by Soil Conservation Service technicians on the basis of "prevailing condition" in the field rather than the "average of all tests made."

The erosion data were taken from published records of the Conservation Surveys Division, Soil Conservation Service. These data were supplemented by notes taken by researchers on the progress of erosion in each field up to the time each crop was harvested.

SPECIAL FEATURES OF THE TERRITORY COVERED

In the High Plains, wheat is raised either by the continuous culture or fallow system. In the northern part of the area studied, more records were made of summer-fallowed fields than of fields cropped year after year to wheat. The reverse was true in the southern part. However, the records provided fair samples of both methods of wheat growing in the territory as a whole.

The average annual rainfall for the whole region during the period 1945-49 was 19.81 inches. This was 6 percent above normal. With the rainfall above average for such a long period, the wheat crop in several localities had more than one chance to make as high a yield as the fertility of the soil would permit. This suited the purpose of the study since the factor limiting yields thus was the available plant food instead of the moisture supply as in many years. It gave the land a full chance to show what it was able to produce.

Although dry-land agriculture has been carried on in certain parts of this area for a long time, farming methods have advanced with the times. Modern methods of farming prevailed generally in the area during the 1945-49 period. The choice new varieties of wheat had been introduced, and although they had not fully taken the place of others in any one spot, their distribution and the extent of their use were fairly uniform throughout the region. The better varieties were grown on 70 to 90 percent of the wheat acreage during the 1945-49 period.

For the region as a whole, average yields were 60 percent higher under summer fallowing than under straight wheat farming. This difference in favor of summer fallow does not represent the full advantage of summer fallowing in the northern part of the southern High Plains, whereas it is greater than can usually be expected in the southern part.[4]

RESULTS OF THE STUDY

The study showed (1) that erosion has been robbing the wheat farmers' lands of part of their possible yield; and (2) that crop removals of plant food, over and above that put back in the soils by legumes and fertilizers, have also taken their toll.

In order to provide a basis for analyzing the effects of erosion and crop removals on grain yields in the light of the ups and downs of other conditions affecting yields, the yields obtained under different rainfall, soil, and agronomic conditions were determined. This analysis, based on 540 records, is shown in table 1.

The study showed that although low moisture supply can never be eliminated as a factor in crop yields, it is relatively less important than other factors in wet years.

With an increase in the moisture supply during the January-May growing season, the wheat yield also increased up to the point where 7 inches of effective rain were received. In many cases, however, more moisture was received than the crops could use. With more than 7 inches, for example, yields fell off. This reduction may have been due in part to damage by diseases brought on by wet weather or to other unfavorable conditions that go along with wet weather.

The amount of weed growth made a difference in the yield. Moderate weed growth at the time the ground was being prepared for planting cut back the wheat yields about 5 bushels per acre. Allowing the weeds to grow on to maturity did not cause much greater reduction in yield. The severe cut-back in yield from fields with moderate weed growth as compared with the yields from fields with no weeds showed the importance of controlling weeds in the early stages of their growth.

More of the seeding was done the first 10 days of September than in any other 10-day period, and the highest average periodic yield was obtained from seedings made during this period. Both earlier and later plantings gave smaller yields but the penalty for planting too soon was much the greater. Nearly as much yield was lost by sowing 10 days too soon as by sowing 70 days too late. However, fewer wheat growers planted early than late.

Within the limits imposed by the natural capability of the land, the most important conditions affecting yields were

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[4] FINNELL, H. H. BEHAVIOR OF SUMMER FALLOW UNDER VARYING SEASONAL AND CLIMATIC CONDITIONS. Okla. Agr. Expt. Sta. Bul. B-319: 142-147. 1948.

Table 1.—*Wheat yields averaged according to significant variables, 1945–49*

Condition	Number of fields	Mean yield of wheat per sowed acre [1]
Average duration of cultivation:		*Bushels*
2.01 years	50	26.1
6.37 years	78	23.3
27.01 years	412	19.1
Erosion removals:		
None to slight	90	22.8
Moderate	298	20.5
Severe	152	18.7
Weed growth during preparation:		
None	315	21.5
Light	161	19.8
Medium	49	16.7
Heavy	15	16.1
Initial soil-moisture penetration:		
0 to 9 inches	141	16.9
10 to 19 inches	109	19.2
20 to 29 inches	129	19.2
30 to 39 inches	52	21.8
40 inches and more	109	26.9
Soil textures:		
Clay loams	320	22.5
Intermediate textures	155	17.0
Sandy loams	65	18.1
Time of seeding:		
Late August	20	17.3
September 1-10	141	23.7
September 11-20	134	21.8
September 21-October 20	131	19.8
October 21-December 10	110	16.1
December 11-20	4	11.7
Effective rainfall during growing season (January to May, inclusive):		
Less than 2.0 inches	49	15.5
2.0 to 2.9 inches	128	17.5
3.0 to 3.9 inches	167	20.8
4.0 to 4.9 inches	46	20.9
5.0 to 5.9 inches	78	24.1
6.0 to 6.9 inches	22	28.4
7.0 to 7.9 inches	45	22.1
8.0 inches and more	5	19.6

[1] Average differences between means were all highly significant (1-percent point).

amount of weed growth and date of seeding. Both weed growth and time of seeding can be controlled by the farmer as part of his regular farming operations, subject only to current weather fluctuations. The character of the farming operations, in fact, not only has a strong bearing on the efficiency of moisture utilization by the present crop, but also has long-time effects on rates of erosion and fertility levels. These, in turn, are in time reflected in crop yield.

Rainfall during the January-May period was the principal climatic factor affecting yields. The amount of summer rainfall may be vital to the storing up of soil moisture in a dry year, but during the 1945-49 period of above-normal rainfall it was the length of time elapsing between crops more than the amount of rainfall that determined the initial moisture supply.

Soil texture played a part in soil-moisture storage and was also associated with variations in available fertility. For various reasons, higher yields were produced on both the heavy and light soils than on soils of intermediate textures.

What was the relation of erosion to wheat yield? The 799 cases studied included 491 cases of wheat grown after wheat and 308 cases of wheat grown on summer-fallowed land. The relation of yield to different degrees of erosion, for wheat grown under each system of culture, is summarized in table 2.

TABLE 2.—*Relation of degree of wind-erosion damage to wheat yields under continuous culture and fallow systems of production, 1945-49*

CONTINUOUS WHEAT

Degree of erosion	Records	Mean yield of wheat per sowed acre [1]
	Number	*Bushels*
None to slight	69	19.2
Moderate	292	18.7
Severe	130	16.8

FALLOWED WHEAT

Degree of erosion	Records	Mean yield of wheat per sowed acre [1]
None to slight	89	34.1
Moderate	79	30.5
Severe	140	25.6

[1] The differences between means are significant at 5-percent point for continuous wheat, and highly significant at 1-percent point for fallowed wheat.

Where wheat was grown after wheat, the average penalty of moderate erosion was 0.5 bushel per acre; that of severe erosion, 2.4 bushels per acre. Although these losses of yield appear small, there were enough records to make the findings conclusive.

Where summer fallowing was used as a means of preparing the land, and the moisture and fertility resources of two seasons thus became available to make one crop, the losses in yield per acre due to erosion damage were larger than where wheat was grown year after year. The loss of production on fallowed land due to moderate erosion averaged 3.6 bushels per acre. Severe erosion resulted in a loss of 8.5 bushels per acre. On a yearly basis this amounts to a loss of 1.8 bushels per acre for moderate erosion and nearly 4.3 bushels for severe erosion.

The seemingly greater effect of erosion on yields of summer-fallowed land does not mean that the erosion damage in areas employing the summer-fallow method was more severe, but rather emphasizes the definite fertility ceiling imposed by erosion. Erosion damage operates in much the same manner as an unfavorable natural land capability. Ample moisture will not boost the yield above a certain limit, so that even summer fallowing fails to produce all the benefits normally expected. Soil erosion appears to damage the ability of the land to release available plant food, as well as its capacity to store up maximum moisture.

Seasonal conditions point often to the need for a summer-fallow practice in the low-rainfall margins of the Plains. However, the deep fertile soils that respond most profitably to summer fallowing occur only sparingly in the areas of scant rainfall. Hence, the opportunities of using summer fallow to maintain crop cover for erosion control and to produce good yields of grain are fewer under marginal conditions than in areas of richer, deeper soils.

Yet erosion control is essential in areas where summer fallowing can be effectively practiced. Very strict control measures, in fact, appear to be justified where failure to control erosion over a short span of years results in a loss in yield of more than 8 bushels per acre.

DECLINE OF PRODUCTIVITY

Soil erosion does not account for all of the decline of productivity observed. Part of the loss of yield must be charged to depletion of fertility due to removal of nutrients in the crops harvested. In table 3 the losses of productivity due to cropping and to soil erosion are shown separately. This separation was made by noting the average degree of erosion in the different

TABLE 3.—*Average per-acre decline of productivity of High Plains wheatlands due to crop removals and erosion*

Kind of land	5-year average yield of wheat	Loss of productivity due to removals—		
		By crops	By erosion	Total
	Bushels	*Bushels*	*Bushels*	*Bushels*
New land[1]	26.1	0.0	0.0	0.0
6-year-old land	23.3	.5	2.3	2.8
27-year-old land	19.1	2.8	4.2	7.0

[1] Average length of time in cultivation, 2 years.

age classes of cultivated land, and then subtracting the decline in wheat yield due to erosion alone from that caused by length of cultivation and erosion combined. This provided a basis for calculating the rate of soil depletion due to unreplaced removals of nutrients by crops.

The rapidity of soil depletion depends in some degree on the manner in which it occurs. Depleting the soil by crop removals has made a comparatively steady drain upon the land throughout the years. Although few nutrients are removed when a crop fails because of drought, their removal is only temporarily delayed. The plant food that would have been taken up is available for use by a bumper crop later. Hence, in the long run, any loss of yield resulting from the removal of nutrients from the soil by crops may be regarded as fairly proportional to the length of time the land was cultivated.

Depletion of the soil by erosion removals followed a different pattern. Crop yields declined faster during the first few years of erosion than later. Productivity losses that started at a rate of about six-tenths bushel of grain per acre per year shrank to a rate as low as one-tenth bushel after 10 to 20 years of erosion.

It is reasonable to suppose that the slowing down of erosion damage after a decade or two was due partly to the erosion resistance of the more compact clay laid open in the subsurface layer of soil, partly to the exhaustion of the organic matter in the rich surface soil. How much each of these contributed to the slowing-down process remains an unanswered question.

Just as weed control to reduce the wastage of water stored in the soil was most effective when carried out early, so the control of erosion at the very outset of cultivation was important in keeping the land rich and productive. If erosion could be completely controlled from the start, the wearing out of land would be slowed down virtually to the rate caused by crop removals alone.

It is apparent from the data in table 3 that a gradual decline of 2.8 bushels per acre in yielding power due to cropping over a period of 27 years would amount to a smaller total loss than would a decline due to erosion that starts with a 2.3-bushel loss over an early period of 4 years. This means that where soil depletion is allowed to run wild, and soil nutrients are removed by both crops and erosion, the accumulated loss in the first 10 years due to erosion would be 4½ times as much as that due to crop removals. At the end of 30 years it would still be 1½ times as great. It is the early damage that proves most expensive in the end.

One way of offsetting these declines might be to return fertility to the soil through manure, fertilizers, or soil-building crops. Theoretically, it would seem possible to restore the yielding capacity of soils merely by putting on a little fertilizer or planting legumes. Natural conditions in dry-farming areas, however, make restoration by these measures difficult. Not only is there a scarcity of adapted legumes, but seasonal moisture variations common to the Plains make the use of fertilizer a very delicate operation. There is a constant risk of burning the crops with fertilizer if the amount applied is only a little more than that needed to match the seasonal moisture supply.

There is much yet to learn about manipulating fertilizer applications and using legumes in dry-land agriculture. However, it is clear from the decline in crop yields observed that the time is rapidly coming, if it is not already here, when the application of fertilizer year by year or the rebuilding of soil reserves from time to time with manure crops will be needed.

Sizing Up the Erosion Hazard

The average land slope in the 540-field group was 1.67 percent. But nearly one-fourth of the fields had slopes steeper than 2 percent. Only 8 fields, or 1.5 percent of the total number, had been damaged by water erosion alone; but nearly 26 percent of the fields had a record of combined water and wind erosion. Two fields, which had just been put in cultivation, were untouched by any kind of erosion, and 158 fields were only slightly eroded.

Land use experience shows that there is a small but definite trend toward a greater water-erosion hazard within this territory, and that where land sloping 2 percent or more is to be put in cultivation, the plowing out of native sod should be accompanied by terrace building and contour farming[5]. About 89 percent of all the wheatland erosion damage recorded in this study was due to wind, whereas only 11 percent was due to water.

In order to meet the erosion hazards successfully, it is necessary to understand the rainfall conditions and how the hazards differ in wet, intermediate, and dry years. Variation in rainfall is the most common seasonal condition met with in the Great Plains. Wet and dry seasons are not only common to each field over a period of years, but may occur in different localities in the same year. Thus, rainfall constantly varies in time, place, and degree. Since this study deals with wheatlands in an area where winter wheat is grown to the exclusion of other types, the rainfall of the 1945-49 period was analyzed on the basis of the wheat year from July 1 to June 30, beginning July 1, 1944.

The average rainfall during this period as a whole was above normal. The rainfall of individual wheat years within the period, however, was either above or below normal, as follows: 1945, 99.6 percent; 1946, 88.9 percent; 1947, 130.2 percent; 1948, 89.8 percent; and 1949, 124.1 percent of normal. Within the area studied, extending 350 miles north to south and 200 miles east to west, rainfall differed sufficiently to provide a record of 579 crops produced under three broadly different moisture conditions—134 under marginal conditions (in spite of the fact that the rainfall in this 5-year period averaged above normal), 257 in the semiarid group, and 188 under midmoist conditions. For convenience in discussion, these groups are referred to as dry, average, and wet, respectively. The comparative influence of various factors affecting yields for each of these moisture groupings is indicated in table 4.

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[5] FINNELL, H. H. LAND USE EXPERIENCE IN SOUTHERN GREAT PLAINS. U. S. Dept. Agr. Cir. 820, 19 pp., illus. 1949.

TABLE 4.—*Mean of factors affecting the maintenance of continuous wheat cover, and comparison of yields, in marginal, semiarid, and midmoist years*

Rainfall, production factors, and yields	Moisture class			Significance of differences of means[1]
	Marginal	Semiarid	Midmoist	
Range of effective rainfall..........inches	6 to 7	8 to 11	12 or more	
Average annual rainfall equivalent..........do	11.75	17.18	28.93	
Factors:				
Land capability..........index No.	3.22	3.46	3.31	
Coarseness of soil texture..........do	2.27	2.28	2.10	
Land slope..........percent	1.38	1.66	1.78	**
Depth of soil profile..........feet	4.37	4.14	4.08	
Time in cultivation..........years	13.00	12.94	13.31	
Current erosion removals..........degrees	.45	.26	.23	**
Length of preparation..........weeks	13.51	13.25	13.14	
Initial depth of moisture penetration..........inches	15.15	17.20	18.20	
Crop residues at seeding time..........index No.	2.92	2.73	2.31	*
Weed growth in preparatory period..........do	1.94	1.86	1.67	*
Weed growth at harvest..........do	1.81	1.67	1.39	**
Lateness of seeding after Sept. 1..........10-day periods	5.19	3.48	2.34	**
Intensive rains in preparatory period..........inches	1.02	1.61	2.74	**
Intensive rains in growing period..........do	.25	.64	2.44	**
Yields per acre:				
Forage..........cow months of grazing	.10	.26	.56	**
Grain..........bushels	10.22	16.10	20.04	**

[1] Items without notations of significance showed no significant differences between means of marginal, semiarid, and midmoist years.
*Significant (5-percent point).
**Highly significant (1-percent point).

From this table it will be noted that soil conditions were fairly uniform for all three groups. No significant differences were found in land capability, soil texture, depth of profile, or years in cultivation. Although the historic erosion data were not comparable and are not included, the record of recent and current erosion showed that wind action prevailed as the major hazard. It was twice as severe in the dry years as in the wet years.

The range of 15 to 18 inches in average initial depth of soil-moisture penetration reflected the increasing amounts of summer rainfall in the dry to wet groupings.

In separating the three groups on the basis of the amount of effective rain that fell during the wheat year, it was found that the effectiveness of rains as measured on cultivated fallow ground did not correctly represent rainfall effectiveness when crop cover was on the land. Part of the so-called excessive fraction of rains which went to waste as surface runoff from bare ground during the preparatory period was not a waste when it fell on a growing crop. Where increasing amounts of the same type of rain fell on a growing crop, both forage and grain yields were substantially increased, which would not have been the case if the rate of runoff losses had remained as high as on bare ground.

The forage and grain yields in wet, dry, and intermediate years may be regarded as an indication of the average state of the ground cover in such years. The cow months of grazing afforded by the crop may be interpreted as a measure of the amount of ground cover during the fall and winter, and the grain yield as an approximate measure of the amount of straw left behind the combine. They provide a rough gage of the adequacy of the residues left by each crop to protect the ground until the next crop makes sufficient fall growth to furnish this protection.

TABLE 5.—*Relative importance (as measured by index numbers) of factors favorable to the continuity of winter-wheat cover in marginal, semiarid, and midmoist years* [1]

Rainfall and factors of production	Moisture class		
	Marginal	Semiarid	Midmoist
Effective rainfall........inches....	6 to 7	8 to 11	12 and more
Mean annual total rainfall........do....	11.75	17.18	28.93
Factors:			
Freedom from weeds in preparatory period........index No....	5		
Amount of initial soil moisture........do....	4	3	
Newness of land........do....	5	3	
Freedom from weeds at harvest........do....	9		7
Amount of excessive-type rain in growing season........do....		7	6
Flatness of land........do....		5	5
Fineness of soil texture........do....			9
Lateness of seeding........do....			5
Proportion of total influence in each moisture class accounted for by above factors [2]........percent....	23	18	32

[1] Refer to table 4 for mean yields.

[2] Percentage of total influence affecting growth of wheat derived from regression coefficients (beta).

The factors important in maintaining a satisfactory continuity of winter-wheat cover in each kind of year are shown in table 5. The index numbers indicate the nature and relative importance of the problems that may be expected under different moisture conditions. For example, the factor that had most to do with the success of the crop in dry marginal years (index 9) was freedom from weeds at harvest—a result of tillage. It was mainly through the timing of this operation and the choice of the right kind of tillage implement that weed competition was reduced to a point where a scant moisture supply contributed its utmost toward growing a crop. In wet years, on the other hand, the factor of greatest influence in making big crops had to do with the inherent quality of the soil, the productive capacity of the land.

DRY YEARS

The group of 134 production records classed as "marginal" represents conditions under which an average yield of only about 10 bushels of wheat per acre was produced. The effective rainfall of 6 to 7 inches in dry years is the amount that may be expected from a total rainfall for the year of about 11.75 inches.

Among the factors influencing the production and maintenance of a wheat cover in dry years, doing away with weed competition especially during the growing season, was of topmost importance. Weeds wasted moisture and tied up plant food which otherwise would have been used to produce pasturage, grain yields, and a more protective vegetative cover than the weeds would furnish. Next in importance was the effect of a rundown or worn-out condition of the soil, roughly indicated by the length of time the land had been in cultivation. This impoverishment of the soil after long cultivation accounts for the frequent comment of farmers that drought hurts crops worse now than it did formerly.

The amount of soil moisture to start the crop was almost equally important.

A separate study of the conditions showed that regardless of the great variation in the amount and distribution of seasonal rainfall, the main factor affecting the build-up of soil-moisture supply was the length of the preparatory period. Of much less importance was the texture of surface soils. Other factors were freedom from weed growth during the preparatory period and the presence of a stubble mulch.

From these observations it is concluded that success in preserving a ground cover and producing a crop of wheat during dry years depends largely upon the use of cultural methods that enable the soil to absorb and hold a good supply of moisture.

WET YEARS

In wet years, for which there were 188 records, there is obviously no risk of losing the protective ground cover through drought. Any erosion hazards that develop in such years would result not from a failure of the crop but from a failure to properly manage the abundant crop residues available for disposal.

The wet years produced roughly 5½ times as much fall and winter growth as the dry years, and at least twice as much stubble was left after harvest (table 4). With an average grain yield of 20 bushels per acre, the quality of the soil was an appreciable factor in determining crop results. And with no shortage of moisture to hinder production, the deep heavy soils on gentle slopes, because of their large fertility reserves and high moisture-using efficiency, showed their ability to produce superior yields.

As in dry years, weed competition during the growing season set the crop back. Seeding later than mid-September proved slightly advantageous during wet years. There was a tendency to seed a little too early for highest grain yields if topsoil moisture was plentiful. Farmers sowed later in dry years because they were waiting for favorable topsoil-moisture conditions.

The average seeding date for wet years was September 23, for moderately wet years October 5, and for dry years October 22. The wide difference between these dates is a strong indication that the surface-moisture condition was the main guide to time of sowing. The exact planting date, provided the crop was seeded within the general planting season, did not seem to have much bearing on yield in the drier years. In the wet years it was never a factor of major importance.

AVERAGE YEARS

An analysis of the 257 records of field yields produced in wheat years of about average rainfall showed that the important factors affecting the outcome of the crop under average rainfall conditions included some factors that were significant in dry years and others that were important in wet years (table 5). Soil depletion and initial moisture were important both in dry years and years of moderate moisture supply. Sloping topography proved to be as great a disadvantage in average years as under wetter conditions.

Extra growing-season moisture coming as high-intensity rain was slightly more beneficial during average years than in wet years. There is no reason to believe that this intensive type of rainfall would not also be beneficial to a growing crop in dry years if it should occur, but it was usually the absence of runoff-producing rains that characterized the year as dry.

The fall and winter ground cover in average years was 2½ times that of the dry years and not quite one-half that of the wet years. The amount of stubble left after harvest was about an average of the extremes observed during the wet and dry years.

RECOGNIZING EROSION DAMAGE

The physical effects of erosion are easily discerned in the field. But the ability of wind-erosion removals to cause serious and permanent damage to the land has not yet been fully recognized by the farmers, land owners, and agriculturists throughout the wind-erosion area. This may be attributed to the fact that reductions in yield due to decline in soil productivity brought about by soil erosion during the past 20 to 30 years, has been partly offset by gains in yield resulting from improvement in wheat varieties and increased mechanical efficiency of farming operations. The depletion of the wheatlands has been masked largely by the improved production of the newer and better varieties.

It was only by comparing the productive capacity of old and new land, of land damaged and undamaged by erosion, planted to the same wheat varieties, and farmed by the same type of equipment, that we have been able to get a true picture of soil depletion.

The average productivity of all the land now in cultivation is 21.8 percent below that of comparable virgin soil, while at the same time the improved varieties of wheat are producing 20.9 percent more than the old varieties which were in general use at the time this land was put in cultivation.

The results of plant breeding have only partly offset the losses resulting from the general wear and tear on the land resulting from removals of plant food by cropping and erosion. They have not compensated for the more extreme conditions existing on approximately one-third of the wheatland acreage.

The decline in productivity on the bulk of long-cultivated land was nearly 27 percent. Wheat yields on the more seriously eroded parts of this land fell about 28 percent below that of the yield level of virgin land. This amounts to a reduction of 7 bushels per acre. Studies at three experiment stations in the area have shown that the average gain in yield due to introduction of new varieties was only 5¼ bushels. The net loss in yield was nearly 2 bushels. Had it not been for the fertility depletion attributable to accelerated erosion, the current yield level could have been substantially higher than the long-time average.

Wheatlands which have been severely eroded have sustained a 2-percent annual loss of productivity during the first few years of cultivation. Even after 27 years the loss is continuing at the rate of 1 percent annually.

PROBLEMS PRESENTED

The fact that recent erosion has been caused mainly by wind, and that soil removals from dry places are relatively large, gives rise to some critical conservation problems. Because of the risk of losing the cream of the soil-fertility reserve of new land during the first few years of cultivation, special efforts should be made to prevent erosion of such land as soon as it is put in cultivation.

At the same time, the fact that older fields have already sustained heavy erosion losses is no excuse for allowing the unnecessary waste to continue. Furthermore, where fertilizers and legume-crop manures are used to improve the productivity of long-cultivated land, equally strong erosion-control measures are needed to safeguard the productivity of this land.

Efforts to maintain the fertility level or to raise it while the land is being used for the production of cultivated crops are continuously opposed by active forces of deterioration. Hence, any level of fertility regained by means of fertilizer or soil-building crops should be considered a temporary one. The fertility level of the soil of virgin land likewise becomes temporary when the sod is plowed.

Since dry-land agriculture is a fairly recent use of southern Great Plains land resources, we are still a long way from reaching the full extent of the depletion that might result from crop removals alone. The fact that we have already worn out and abandoned some of the low-capability lands, however, is ample proof that such lands should have been kept in grass. Sandy and shallow soils wear out too fast under cultivation even with the use of the best erosion-control methods known.

Erosion is a greater threat to the continued usefulness for crop production of the high-capability lands than soil depletion resulting from uncompensated removals of soil fertility in the crops harvested.

IMPORTANT IMPROVEMENT MEASURES

From all the viewpoints afforded by the present stage of investigations, it must be concluded that **the first step toward maintaining high yields on new land or rebuilding productive capacity in depleted soils is to bring erosion effectively under control.** Where adequate control of erosion on cultivated land is not possible, such land should no longer be used for cultivated crops.

Among the next logical steps in developing better land use for the southern High Plains are (1) developing the use of soil-building crops in rotations with grain and forage; and (2) perfecting the techniques of applying chemical fertilizers when the moisture supply is limited.

Neither of these possibilities has been fully accepted by High Plains farmers and agronomists. In most parts of the area, only the most cautious experimenting has been started; but with the net loss in yield on nonconservation farms steadily mounting, we cannot expect to offset soil depletion very much longer merely by improving crop varieties and increasing the mechanical efficiency of farm operations. Soil conservation measures of a positive nature are necessary. To attain them on a practical basis, better methods of soil building than are now available must be devised for High Plains wheatlands.

SUMMARY

Depletion of High Plains wheatlands began with the first breaking of the sod. Abandonment due to erosion damage has been taking place at a rapid rate on low-capability lands. On the most severely damaged lands not yet abandoned, the level of production has fallen an average of 7 bushels per acre in 27 years. Soil erosion was responsible for 4.2 bushels of the loss. Crop removals which were not offset through fertilizer application and the planting of legumes were responsible for 2.8 bushels of the loss. The erosion removals of the rich topsoil brought about lower crop yields four to five times as fast as later similar removals of subsurface and subsoil material.

Eighty-nine percent of the soil loss from the nearly flat wheatlands of less than 2-percent slope in the southern High Plains was due to wind action, 11 percent to water action.

All cultivated lands in areas of 14 to 28 inches of rainfall should be protected through the application of suitable wind-erosion-control measures. In addition, all slopes of 2 percent or more should be terraced and contour-farmed from the time they are first put in cultivation.

All precautions against erosion which tend to increase moisture-using efficiency should be redoubled when the loss of vegetative cover is threatened by drought. The conservation of crop residues never ceases to be important regardless of whether it is done to protect the surface soil from wind and water erosion, to increase the infiltration of water, or to maintain the supply of organic matter in the soil.

In selecting lands for wheat raising it is advisable, whatever the long-time rainfall conditions may be, to choose only high-capability land for cultivation, and then to consistently prevent both wind and water erosion throughout the cultivated life of the fields. It is when the fertility ceiling becomes the chief limiting factor of production, as during seasons of plentiful moisture supply, that such measures prove their worth in high yields.

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